A STATISTICAL ANALYSIS OF THE U. S. CROP SPRAYING PROGRAM IN SOUTH VIETNAM

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FOREWORD

This report is one of a series of Rand studies that examine the organization, operations, motivation, and morale of the Viet Cong and North Vietnamese forces that fought in South Vietnam.

Between August 1964 and December 1968 The Rand Corporation conducted approximately 2400 interviews with Vietnamese who were familiar with the activities of the Viet Cong and North Vietnamese army. Reports of those interviews, totaling some 62,000 pages, were reviewed and released to the public in June 1972. They can be obtained from the National Technical Information Service of the Department of Commerce.

The release of the interviews has made possible the declassification and release of some of the classified Rand reports derived from them. To remain consistent with the policy followed in reviewing the interviews, information that could lead to the identification of individual interviewees was deleted, along with a few specific references to sources that remain classified. In most cases, it was necessary to drop or to change only a word or two, and in some cases, a footnote. The meaning of a sentence or the intent of the author was not altered.

The reports contain information and interpretations relating to issues that are still being debated. It should be pointed out that there was substantive disagreement among the Rand researchers involved in Vietnam research at the time, and contrary points of view with totally different implications for U.S. operations can be found in the reports. This internal debate mirrored the debate that was then current throughout the nation.

A complete list of the Rand reports that have been released to the public is contained in the bibliography that follows.

Bibliography of Related Rand Reports

For a description of the Viet Cong Motivation and Morale Project and interviewing process, the reader should first consult W. Phillips Davison, *User's Guide to the Rand Interviews in Vietnam,* R-1024-ARPA, March 1972.

These reports can be obtained from The Rand Corporation.

RM-4507/3   Viet Cong Motivation and Morale in 1964: A Preliminary Report, J. C. Donnell, G. J. Pauker, J. J. Zasloff, March 1965.

RM-4517-1   Some Impressions of the Effects of Military Operations on Viet Cong Behavior, L. Goure, August 1965.

RM-4552-1   Evolution of a Vietnamese Village -- Part I: The Present, After Eight Months of Pacification, R. M. Pearce, April 1965.

RM-4692-1   Evolution of a Vietnamese Village -- Part II: The Past, August 1945 to April 1964, R. M. Pearce, April 1966.

RM-4699-1   Some Impressions of Viet Cong Vulnerabilities: An Interim Report, L. Goure, C.A.H. Thomson, August 1965.

RM-4703/2   Political Motivation of the Viet Cong: The Vietminh Regroupees, J. J. Zasloff, May 1968.

RM-4830-2   Viet Cong Motivation and Morale: The Special Case of Chieu Hoi, J. M. Carrier, C.A.H. Thomson, May 1966.

RM-4864-1   Observations on the Chieu Hoi Program, L. W. Pye, January 1966.

RM-4911-2   Some Findings of the Viet Cong Motivation and Morale Study: June-December 1965, L. Goure, A. J. Russo, D. Scott, February 1966.

RM-4966-1   Some Effects of Military Operations on Viet Cong Attitudes, F. H. Denton, November 1966.

RM-4983-1   A Profile of Viet Cong Cadres, W. P. Davison, J. J. Zasloff, June 1966.

RM-5013-1   A Profile of the PAVN Soldier in South Vietnam, K. Kellen, June 1966.

RM-5086-1   Evolution of a Vietnamese Village -- Part III: Duc Lap Since November 1964 and Some Comments on Village Pacification, R. M. Pearce, February 1967.

RM-5114-1   A Look at the VC Cadres: Dinh Tuong Province, 1965-1966,
             D.W.P. Elliott, C.A.H. Thomson, March 1967.

RM-5163/2   Origins of the Insurgency in South Vietnam, 1954-1960:
             The Role of the Southern Vietminh Cadres, J. J. Zasloff,
             May 1968.

RM-5239-1   Insurgent Organization and Operations: A Case Study of
             the Viet Cong in the Delta, 1964-1966, M. Anderson,
             M. Arnsten, H. Averch, August 1967.

RM-5267/2   Some Observations on Viet Cong Operations in the Villages,
             W. P. Davison, May 1968.

RM-5338   Two Analytical Aids for Use with the Rand Interviews,
             F. Denton, May 1967.

RM-5353-1   The War in the Delta: Views from Three Viet Cong Battal-
             ions, M. Gurtov, September 1967.

RM-5414-1   Viet Cong Cadres and the Cadre System: A Study of the
             Main and Local Forces, M. Gurtov, December 1967.

RM-5423-1   Viet Cong Logistics, L. P. Holliday, R. M. Gurfield,
             June 1968.

RM-5446-1   An Evaluation of Chemical Crop Destruction in Vietnam,
             R. Betts, F. Denton, October 1967.

RM-5450-1   A Statistical Analysis of the U.S. Crop Spraying Program
             in South Vietnam, A. J. Russo, October 1967.

RM-5462-1   A View of the VC: Elements of Cohesion in the Enemy Camp
             in 1966-1967, K. Kellen, November 1969.

RM-5486-1   Viet Cong Recruitment: Why and How Men Join, J. C. Donnell,
             December 1967.

RM-5487-1   The Viet Cong Style of Politics, N. Leites, May 1969.

RM-5522-1   Inducements and Deterrents to Defection: An Analysis of
             the Motives of 125 Defectors, L. Goure, August 1968.

RM-5533-1   The Insurgent Environment, R. M. Pearce, May 1969.

RM-5647   Volunteers for the Viet Cong, F. Denton, September 1968.

RM-5788   Pacification and the Viet Cong System in Dinh Tuong: 1966-
             1967, D.W.P. Elliott, W. A. Stewart, January 1969.

RM-5799   The Viet Cong in Saigon: Tactics and Objectives During the
             Tet Offensive, V. Pohle, January 1969.

PREFACE

Since July 1964, The RAND Corporation's field office in Saigon has been engaged in studies of the Viet Cong, under the sponsorship of the Office of the Assistant Secretary of Defense for International Security Affairs (ISA) and the Advanced Research Projects Agency (ARPA). In February 1966, ARPA asked that RAND focus part of its effort on an evaluation of the joint United States and Government of Vietnam aerial crop spraying program. (The crop spraying program should not be confused with the overall herbicide program, which includes the defoliation of trees and underbrush to destroy enemy cover.) Specifically the RAND team was asked to concentrate on the following aspects of the program:

1. Attitudes of the rural population toward U.S./GVN use of herbicides on crops.

2. Effects of crop destruction on the rural population.

3. Effects of crop destruction on the Viet Cong.

4. Methods to reduce the impact of negative attitudes on the part of the rural population.

This Memorandum is concerned primarily with the effects of crop destruction on the Viet Cong. The form of the analysis and the type of conclusions reached allow some things to be said about the effects of the program on the rural population, but even though that aspect is in no way less important, the bulk of the analysis is directed toward the effects of the program on the Viet Cong. Other RAND memoranda will discuss those aspects of the crop destruction program that are not considered here. For example, see R. Betts and F. Denton, An Evaluation of Chemical Crop Destruction in Vietnam, RM-5446-1-ISA/ARPA. (forthcoming).

The data upon which this study is based came principally from three sources: (1) RAND interviews with ex-Viet Cong (prisoners and defectors), (2) U.S. Agency for International Development statistical abstracts, and (3) crop destruction operations data from official sources.

SUMMARY

This Memorandum aims at an improved understanding of the effects of crop spraying operations on Viet Cong rice consumption, by examination of relevant statistical indicators. Regional averages of individual VC daily rice rations were used as an indicator of the pattern of VC rice consumption; the variation in rice rations from region to region was examined, using multiple regression techniques, in the context of variations in other regional characteristics including the percentage of regional rice lands sprayed with herbicides.

It was found that VC rice rations vary in remarkably close relationship with standard regional economic variables and a foreign sanctuary factor. No significant relationship was noted between rice rations and the percentage of regional rice lands sprayed. VC rice rations were found to be a function of regional rice production and population variables and a foreign sanctuary factor taken to be the distance from the center of a region to the Cambodian or Laotian border. Although no direct relationship was found between VC rice rations and the percentage of rice lands sprayed, it was possible to assess the effects of crop spraying simply by varying the rice production term in the regression model and noting the resultant variation in the VC rice ration variable. The effects of crop spraying were simulated in this way and found to be small. For the area hardest hit in 1966 (approximately 23 percent of the crop was destroyed), the model shows a decrease in average rice ration of approximately 5 percent (from 660 grams per VC per day to 627). On the other hand, losses incurred by civilians are considerable: the analysis indicates that the civilian population seems to carry very nearly the full burden of the results of the crop destruction program; it is estimated that over 500 civilians experience crop loss for every ton of rice denied the VC.

The results of this study strongly imply that the relationship between the VC and the rice economy is so intimate and pervasive that significant or crippling effects on VC rice consumption would result only if a major proportion (perhaps 50 percent or more) of the rural economy were destroyed.

The U.S./GVN crop destruction program, then, has an insignificant effect on Viet Cong rice consumption and may be counterproductive. It is suggested that the program be taken under serious review.

ACKNOWLEDGMENTS

The author wishes to express appreciation to many members of The RAND Corporation for the interest they have shown in this work, and for their advice and assistance.

The rice ration data were ably collected during many hours of interviewing in the provinces of South Vietnam by the RAND Vietnamese staff and field directors Russell Betts, James Carlson, and Douglas Scott.

Helpful comments, both critical and encouraging, on the draft were made by S. Cochran, F. Denton, D. C. McGarvey, M. Palmatier, V. Pohle, and S. Winter.

The computer runs were supervised by N. Jacobsen.

Any shortcomings that remain are the sole responsibility of the author.

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I. INTRODUCTION

The analysis reported here makes use of standard statistical tech-
niques and relies heavily upon data collected directly in the field by
RAND interrogation teams. A detailed account of the course of the
analysis is provided in Section II, including the statistical model of
Viet Cong rice rations generated as a result.

In Section III use of the model permits estimates of the effects
of the crop destruction program on the VC. In Section IV these estimates
are compared with estimates of losses incurred by civilians.

In Section V the effectiveness of the crop spray program is seen
to be very low. Effectiveness is defined as amount of rice denied the
VC per ton of rice destroyed by spray. The basic reason for the low
effectiveness of the program is that the VC are a very small percent-
age of the population, yet they control or have access to almost the
entire rural economy in one fashion or another. These two facts form
the basis for many, if not most, of the problems the U.S./GVN effort
faces, and they tend to push the effectiveness of this and many other
allied programs to a low level.

In Section VI a simple deductive model relates VC consumption to
overall VC tax rate and rice production. Under certain reasonable
assumptions, the behavior of the model supports the empirical findings.

The principal conclusion of the study, noted in Section VII, is
that the returns of the crop destruction program, in terms of decreas-
ing VC rice consumption, are so limited as to suggest that the program
should be taken under serious review.

II. ANALYSIS

The specific objective of this study was to detect the effects of the crop spray program on VC <u>rice consumption</u>. The analysis does not explicitly address the possible effects of the crop destruction program on the VC logistics system, nor does it consider ways in which the program might stimulate refugee flows.[*] Also the analysis is concerned with the effects on VC rice consumption as seen from a regional level, not local effects; the magnitude of the program (that is, the amounts of rice destroyed) is large enough that, were it having a significant effect on VC rice consumption, these effects would be noticeable on a regional scale.

Regional variations in VC rice rations have been used as an indication of the general state of VC rice consumption patterns. These rice ration data were obtained from a sample of 207 ex-Viet Cong (prisoners and defectors) interviewed by the RAND field teams in South Vietnam (see Tables 1 and 2).

The rice ration data were aggregated by region as shown on the map in Fig. 1 (regions are labeled 1 through 16). The mean rice ration was calculated for each region; as is seen in Table 1 there is considerable variation from region to region (441 grams per VC per day in region 8 to 875 grams per VC per day in region 16).

<u>A priori</u>, it is known that some of the variation in average VC rice ration is due to a variation in the kind of VC diet found in the different regions. In Central Vietnam, for example, manioc is eaten in greater proportions than it is in the Mekong Delta, or in the coastal plains meat and fish very likely make up a higher percentage of the total caloric intake than would be the case in the highlands. To a certain extent, the absolute amount of rice consumed per VC per day in any given area is dependent upon characteristics of that area, such as the amount of rice produced relative to the size of the population,

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[*]It is the author's feeling that the crop spraying program, by itself, plays a minimal role in forcing refugee movements. General insecurity seems to be the most important motivational factor.
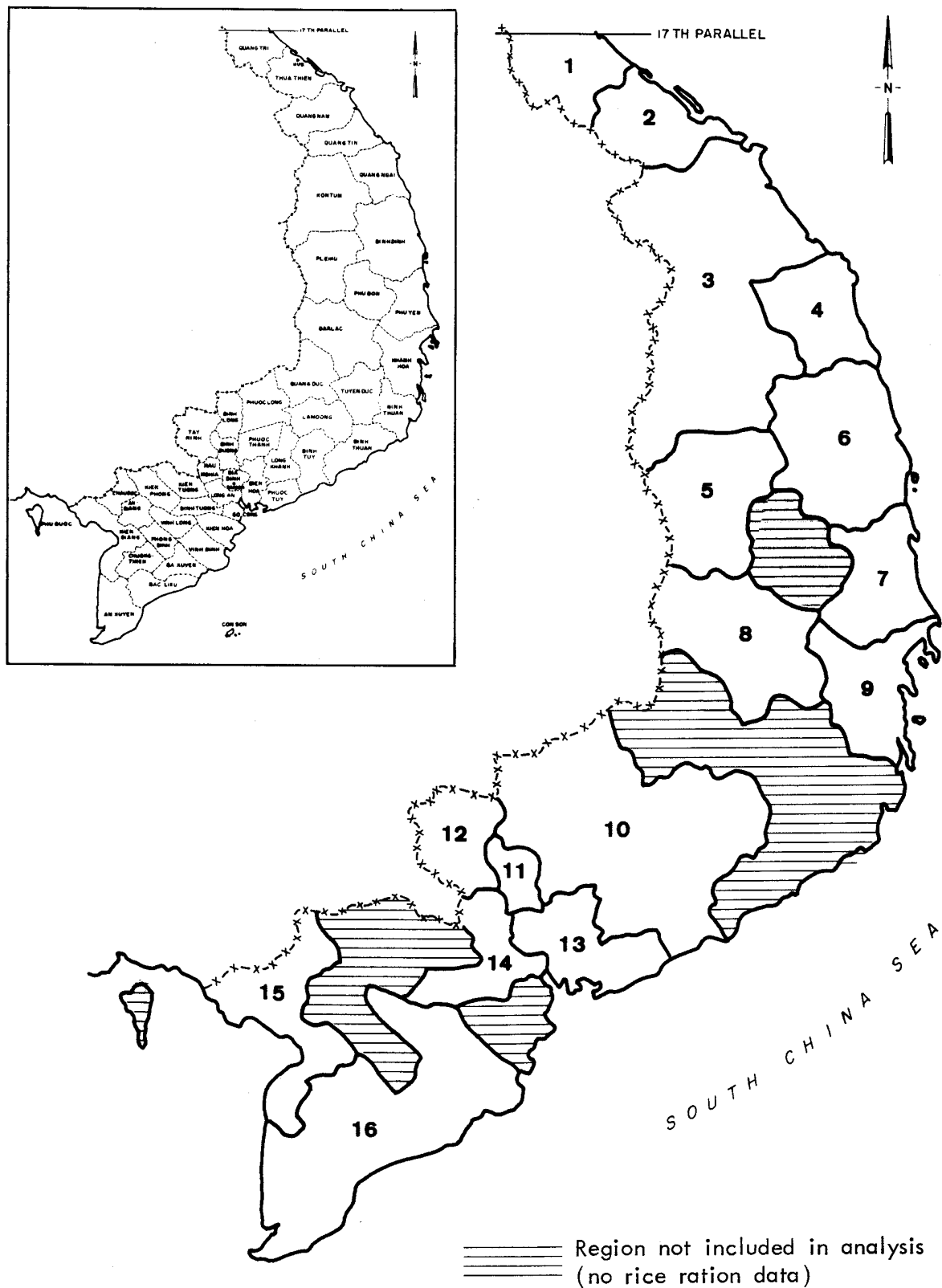
Fig. 1—Regional aggregates used in analysis

Table 1

VIET CONG RICE RATION DATA SAMPLE

Region	Sample Size	X_R Mean (Gms/day)	Standard Deviation	Coefficient of Variation
1	11	654	198	.303
2	13	519	132	.254
3	13	611	111	.181
4	10	575	205	.356
5	15	603	135	.224
6	33	574	176	.307
7	13	560	146	.261
8	9	441	149	.337
9	7	600	117	.195
10	16	656	133	.203
11	12	700	227	.324
12	14	718	87	.122
13	16	734	107	.146
14	8	703	152	.216
15	7	768	104	.135
16	10	875	168	.192

Table 2

INDIVIDUAL RICE RATION DISTRIBUTIONS BY REGION

Ration (gms/day)	Regions																Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
225											1						1
250	1	1		2		3	1	2									10
300						1											1
320								1									1
375		2			2	2	1				1						8
400					1			1			1						3
425													1				1
440	1																1
500	2	5	6	2	2	9	5	4	4	2	2		2	2			47
550		1															1
600					2	3	2				1						8
625		2	2	2		2					1		1	1	1		12
650					1												1
700		1	1		4	4	1		1		1						13
725											1						1
750	6	1	4	4	3	8	3	1	2	10	6	12	13	4	5	6	88
1000	1					1							1	1	1	3	8
1250											1					1	2
																	207

Note:

There is a tendency for the sample to cluster around multiples of .5 x 250 grams. This is most likely because the VC have settled upon the use of discarded condensed milk cans as convenient units of measurement (one can holds 250 grams of rice); they tend to issue rice in increments of cans (for example, 1, 2, or 3 cans) or, less frequently, half-cans (for example, 1-1/2 or 2-1/2 cans corresponding respectively to 375 grams and 625 grams).

the fertility of the land, population density, and so on. Also, some rice is infiltrated from Laos, Cambodia, and North Vietnam for use by the VC; therefore, the relationship of any given area within South Vietnam to a foreign sanctuary is expected to play a role in determining the size of VC rice rations in that area. Finally, after controlling for local factors and the fact that rice is being infiltrated, if the crop destruction program is having an effect on VC rice consumption in a given region, rice rations should decrease in proportion to the intensity of the crop spraying operations in the region. Thus, to summarize, the a priori expectation is that the level of regional average VC rice rations is determined to a great extent by three sets of regional characteristics:

(1) agricultural and population factors

(2) relationship of the region to a foreign sanctuary where rice stores are located

(3) intensity of crop destruction operations.

Multiple regression techniques were used to examine variations in the rice ration data in the context of variations in factors from each of the above categories.[*] The primary objective was to see if any portion of the variation in regional average rice rations could reasonably be attributed to the regional variations in the intensity of crop destruction operations. Several variables were used as measures:

(1) estimates of the fraction of regional rice lands destroyed in 1966, D_{66}.

(2) estimates of the fraction destroyed in 1965, D_{65}.

(3) the combined 1965 and 1966 acreage destroyed

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[*] Rice production and population data were taken from Annual Statistical Bulletin, September 1966, USAID-Vietnam. Measures of the intensity of crop destruction operations were derived from field operations data taken from official sources.

Data on amounts of rice infiltrated are difficult to come by; therefore, a very simple indicator was chosen: the shortest distance from the center of a region to the Cambodian or Laotian border (or, in the case of Quang Tri Province, the 17th parallel).

(4) a "dummy" variable equal to zero in regions where no
crops were sprayed; and 1.0 where they were (this
variable was also used in combination with the above
variables).

None of these variables showed statistical significance. Some had
positive coefficients, some negative, and some were so close to zero
the computer program would not print them; all non-zero coefficients
were so small that in each case, significance tests showed their
departure from zero to be a matter of chance or error. The variables
used as measures of regional rice production and population, and the
foreign sanctuary factor (distance to the border) turned out to be
highly significant. A large number of models using linear and non-
linear terms in these variables were tested. The following model was
found to eclipse all others in terms of both statistical significance
and amount of variance explained:

$$X_R = -370 + 1300X_1 - 846 \log_{10}X_1 + 752 \log_{10}X_2 - .75X_3 \qquad (1)$$

$$(55.7) \qquad (121) \quad (79.3) \qquad (91.5) \qquad (24.5)$$

where

X_R = regional average individual VC daily rice ration,
grams/person-day

X_1 = regional annual (June 1965-May 1966) rice production
per capita, metric tons/person-year

X_2 = regional annual (June 1965-May 1966) rice production
per hectare, metric tons/hectare-year

X_3 = closest distance from the center of a region to the
Cambodian or Laotian border, kilometers.

The numbers in parentheses under equation (1) are the overall (55.7)
and partial F ratios. The multiple correlation coefficient (R) is .98,
R^2 is .95, and R^2 corrected for degrees of freedom is .94. In Table 3,
values are shown for X_1, X_2, and X_3 for each of the 16 regions.

An example of the insignificance of the intensity of crop spraying
operations is shown in the following equation:

Table 3

BASIC DATA MATRIX

Region	$\hat{X}_R$ Mean Rice Ration Gms/Person-Day	X_1 Metric Tons Per Person Per Year	X_2 Metric Tons Per Hectare Per Year	X_3 Kilometers	P Population Per Hectare
1	654	.147	1.60	28	10.94
2	519	.182	1.33	31	7.35
3	611	.143	1.19	26	8.28
4	575	.222	1.63	104	7.34
5	603	.065	.77	42	12.00
6	574	.261	1.79	142	6.83
7	560	.204	1.86	158	9.13
8	441	.161	1.00	62	6.25
9	600	.230	2.31	158	10.20
10	656	.080	1.21	87	15.40
11	700	.181	2.05	42	11.22
12	718	.287	2.36	35	8.23
13	734	.201	2.62	92	13.05
14	703	.443	2.20	42	4.98
15	768	.533	1.96	47	3.69
16	875	.772	2.21	143	2.86

$$X_R = -370 + 1300X_1 - 847 \log_{10}X_1 + 754 \log_{10}X_2 - .75X_3 - 14D_{66}$$
$$(40.6) \qquad (124) \qquad (72) \qquad (81) \qquad (22) \qquad (.024)$$

Note that the X_1, X_2, and X_3 terms are virtually the same as in equation (1) where D_{66} was not taken into account. Also note that the F value for the D_{66} term is very low (.024). This means that the deviation of the coefficient from zero is a matter of chance or error.

Equation (1) shows that these results are extremely significant in a statistical sense. For example, an F ratio of 10.35 is significant at the .001 level. The higher F values characterizing the model presented here are an indication that it is significant at a level much below .001, although one cannot say precisely because the exact functional forms of the distributions from which the data are generated are unknown.

The robustness of the model was further illustrated by the way it held up under a rather severe sample deletion test performed by running two additional cases:

(1) Deleting regions 8 and 16 (the extreme values of $\hat{X}_R$).

(2) Deleting regions 5, 8, 9, 12, 15, and 16, thereby including only those regions in which crop destruction operations were conducted in 1966.

In each case the model retained approximately the same parametric form, and although the values of the F ratios were naturally diminished owing to the severe reduction in degrees of freedom, they remained significant. Results of the sample deletion test are summarized in Table 4.

A graphical illustration of how well the model fits the data is shown in Fig. 2. The rice ration values predicted by the model are plotted against those actually observed in the interview data. If the model predicted the observations exactly, all 16 points would fall on the 45 degree straight line and the value of $\bar{R}^2$ would be 1.0; to put it another way, all (100 percent) of the variance in the rice ration data could be explained. As the model stands, $\bar{R}^2 = .94$, which means that the variables X_1, X_2, and X_3 explain 94 percent of the variance.

Table 4

RESULTS OF SAMPLE DELETION TEST PERFORMED ON

$$X_R = \beta_0 + \beta_1 X_1 + \beta_2 \log_{10} X_1 + \beta_3 \log_{10} X_2 + \beta_4 X_3$$

Case	Sample	Remarks	Overall F	R	R^2	$\bar{R}^2$	Standard Error	Degrees of Freedom	β_0	β_{1*}	β_2	β_3	β_4
0	All 16 regions		55.7	.98	.95	.94	± 27 gms	11	-370	1300 (121)	-846 (79.3)	752 (91.5)	-.75 (24.5)
1	Regions 1-7, 9-15	Extreme values deleted	21.3	.95	.90	.86	± 28 gms	9	-336	1290 (35.7)	-816 (34.8)	697 (47.5)	-.71 (17.3)
2	Regions 1-4, 6, 7, 10, 11, 13, 14	Regions with no 1966 crop destruction operations deleted	11.0	.95	.90	.82	± 30 gms	5	-253	1060 (9.2)	-749 (15.7)	723 (34.3)	-.61 (7.7)

Note:

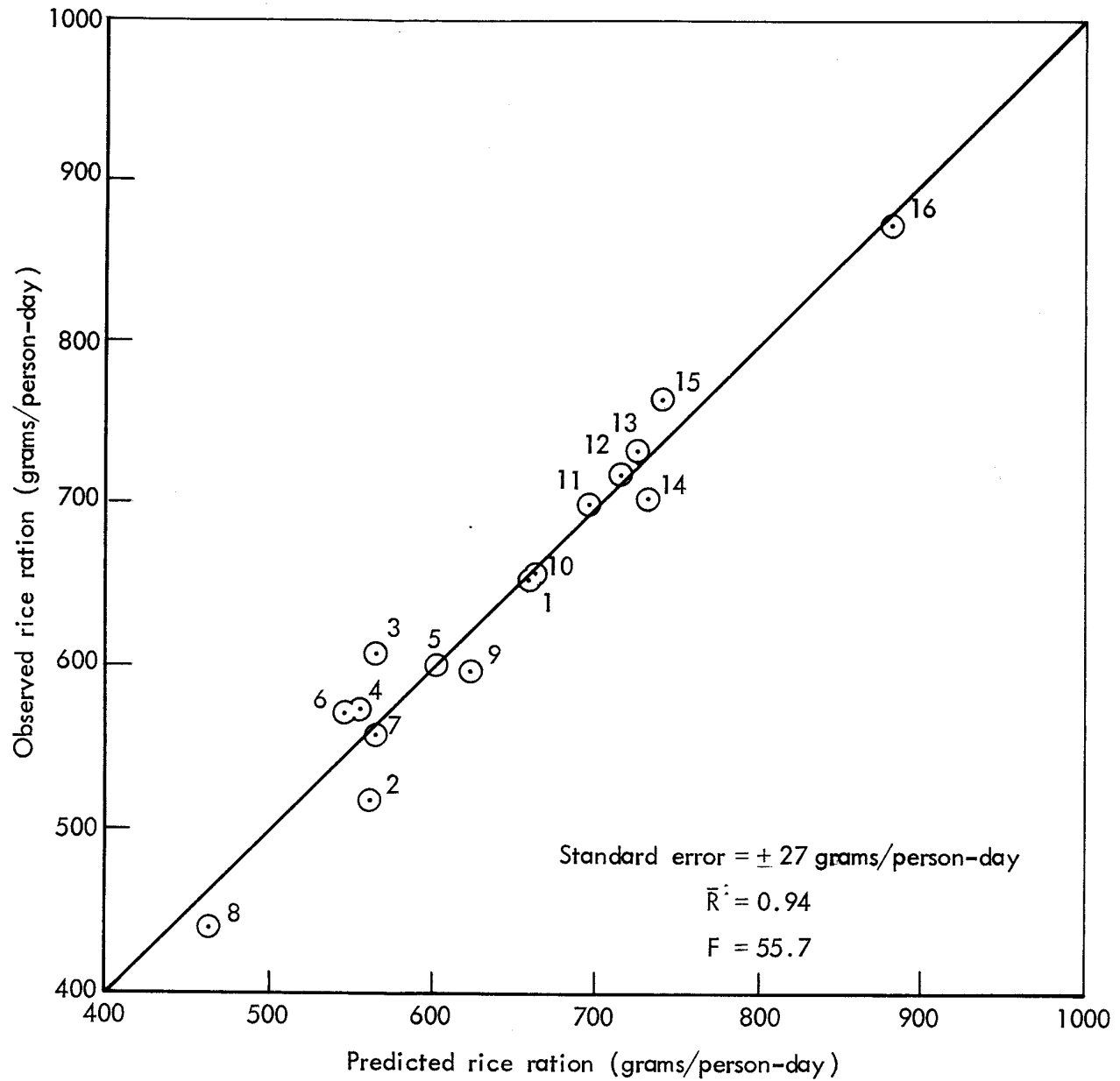Numbers in parentheses are partial F values.

Fig. 2—Goodness of fit: individual VC daily rice ration model

As with most empirical models, there are a number of interpretations. A great deal depends upon the purpose for which the model is used.[*] An assessment of the effectiveness of the crop destruction program suggests a focus upon the way VC rice rations are likely to vary with the decrease in regional rice production brought on by the destruction of some fraction of the crop. The magnitude of this variation will serve as a check on the initial finding that measures of intensity of crop destruction operations in no way explain the variation in rice rations. One could conceivably argue that such a small sample of rice ration data might have entirely missed those segments of the VC that were affected and that is why measures of intensity of the operations did not help explain some of the variance.[**] But since there is an empirical relation that gives rice ration as a function of production, we can vary production by the amount of rice destroyed and see how it affects the rice ration variable.

In the form of the model shown in equation (1), rice production appears in two of the variables, X_1 and X_2; it is helpful in the analysis to isolate its effects to some extent by introducing the following identity:

$$X_2 \equiv pX_1 \tag{2}$$

where p = population per hectare of rice land. Using (2), equation (1) becomes[***]

$$X_R = -370 + 1300X_1 - 94 \log_{10}X_1 + 752 \log_{10}p - .75X_3. \tag{3}$$

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[*] There are many potential applications because the model is a quantitative relationship showing one way in which a "guerrilla" or "national liberation" movement depends upon the indigenous economy and foreign sanctuaries.

[**] If this were the case, however, it would be an _ipso facto_ argument that the program has an insignificant effect on VC consumption.

[***] This is the equation that would, in fact, result if we had used X_1, p, and X_3 in the regression analysis from the very beginning.

In this form rice production appears only in the X_1 variable, making
interpretation much more straightforward. A graphical representation
of the model is shown in Fig. 3. X_R is seen to increase almost
linearly (the slight concavity is due to the log term) for constant
α_1 , which is simply a convenient label for the collection of the
other terms in the equations that are held constant.

$$\alpha_1 \equiv -370 + 752 \log_{10}p - .75X_3.$$

The α_1 range (-200 to 500) covers the range of p and X_3.

The interpretation of equation (3) is very straightforward: as X_1
increases there is more rice (relative to the local population) subject
to VC taxation, confiscation, theft, or covert purchase; as p increases,
for a given value of X_1, there is more rice per given area of rice
land. An increase in either X_1 or p, or both simultaneously, simply
implies that the area is relatively richer in rice and, naturally, it
is expected that VC rice rations will be larger in the more rice-rich
areas. The X_3 term says that after regional characteristics have been
accounted for, VC rice rations decrease by .75 grams per kilometer as
we move away from the border. X_3 does not tell us directly how much
rice is coming across the border, but because it contributes signifi-
cantly in explaining the variation in X_R, it is a clear indication
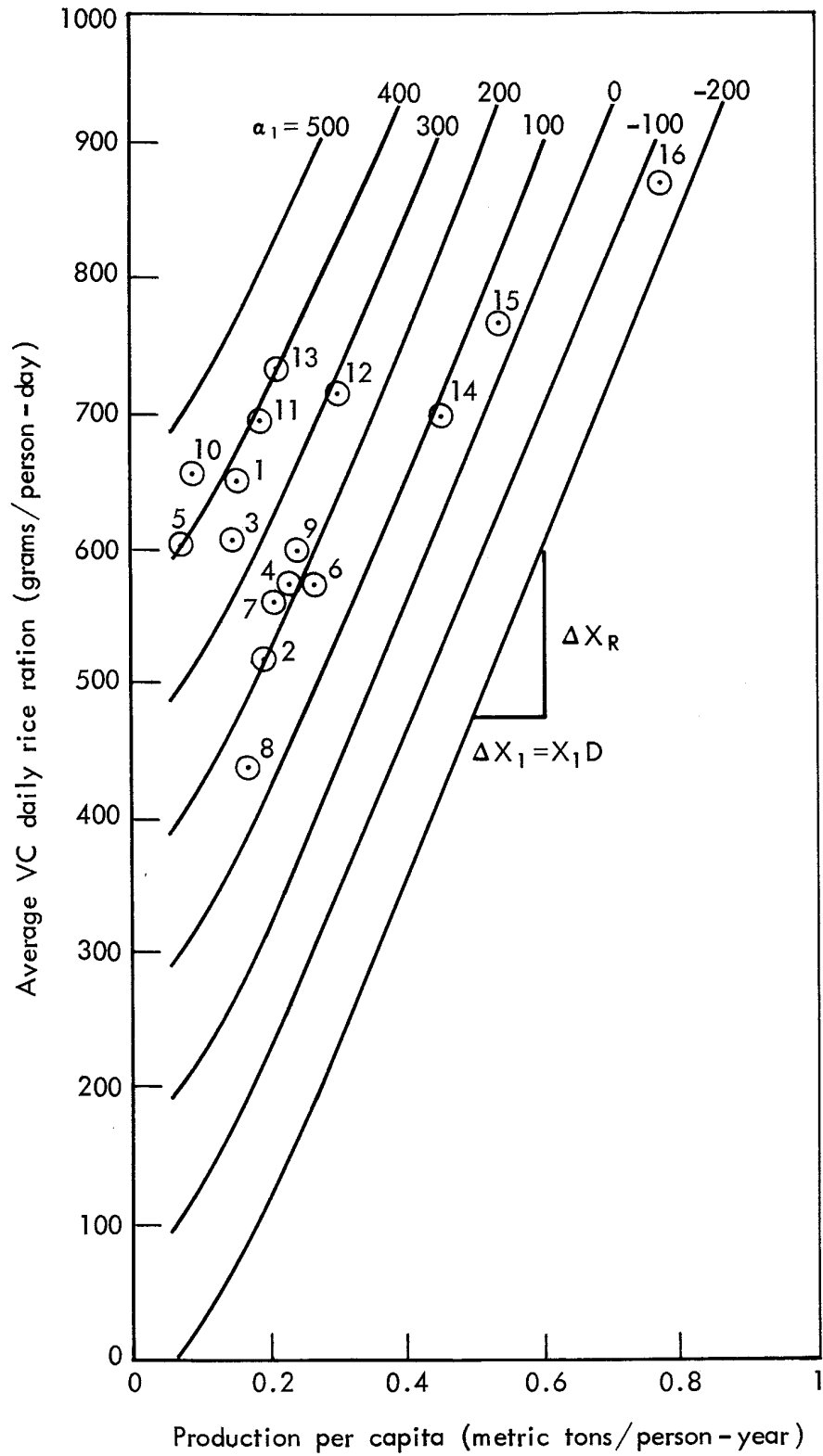that the infiltration of rice is an important factor.

Fig. 3—$X_R = 1300 X_1 - 94 \log_{10} X_1 + \alpha_1$

III. EFFECTS OF CROP DESTRUCTION OPERATIONS
AS PREDICTED BY THE MODEL

The destruction of some fraction D of a regional rice crop can be simulated by calculating the effects of a change in X_1 on X_R. Some error is to be expected because the model is static; however, the estimates given by a static model should retain a high degree of validity and serve as acceptable approximations.

Let the subscripts 1 and 2 refer to "normal" and "after crop spray" conditions respectively. Then the overall loss in X_R is (arbitrarily taken to be positive):

$$\Delta X_R = X_{R_1} - X_{R_2} . \tag{4}$$

Using the basic expression for X_R in (4) gives

$$\Delta X_R = 1300 \ (X_{11} - X_{12}) - 94 \ \log_{10} \frac{X_{11}}{X_{12}} , \tag{5}$$

which can also be written making use of

$$X_{12} \equiv X_{11} \ (1-D) , \tag{6}$$

where D, as defined above, is the fraction of the crop destroyed. Using (6), (5) becomes

$$\Delta X_R = 1300 X_1 D - 94 \ \log_{10} \frac{1}{1-D} . \tag{7}$$

ΔX_R is the result of proceeding downward along the curves in Fig. 3 to the extent dictated by the magnitude of D. Calculations of the fractional decrease in rice rations $\left(\dfrac{\Delta X_R}{X_{R_1}} \right)$ for the ten regions in which herbicide operations were carried out in 1966 are shown in Table 5. Estimates of the proportion D of the 1966 crop destroyed were calculated using the formula:

$$D = 125 \ \frac{S}{A}$$

Table 5

IMPACT OF U.S. AERIAL CROP SPRAY PROGRAM

Region	Number of Crop Destruction Sorties Flown in 1966	D	$\frac{\Delta X_R}{X_{R_1}}$
1	46	.230	.051
2	37	.074	.028
3	60	.063	.015
4	27	.040	.017
6	28	.030	.016
7	38	.133	.053
10	16	.071	.007
11	21	.120	.033
13	6	.009	.003
14	5	.002	.002

where

S = number of crop destruction sorties flown in region in 1966.

A = total area of rice land in region in hectares.

125 = average number of hectares destroyed per sortie.

The results of the calculations tend to support rather strongly the contention that crop destruction operations have a very limited effect on VC rice consumption. For example, in region 1 where 46 sorties were flown in 1966, approximately one-fourth of the crop was destroyed (23 percent); however, the loss to the Viet Cong, as predicted by the model, amounted to a decrease in average daily rice rations of about 30 grams, or approximately 5 percent. Generally, it appears that very large losses have to be inflicted before the effect on X_R begins to look significant. This is illustrated graphically in Fig. 4 where the values of D and $\Delta X_R/X_{R_1}$ shown in Table 5 are plotted in a scatter diagram. Generally, to cause a given percentage of rice loss to the VC, a much greater percentage of the total crop has to be destroyed. An "average" case would be illustrated by the zero-intercept regression line fitted to the points in Fig. 4: for each percentage decrease in VC rice consumption, about 3.7 percent of the regional crop has to be destroyed.

So far the statistical analysis has persisted in giving a dismal picture of the effectiveness of the crop destruction program. Is there a straightforward "common sense" explanation for this?

In Table 6, values for some relevant characteristics are shown for the ten regions where crop destruction operations took place in 1966. The most important sets of numbers are probably those in columns (3) and (4), the VC annual requirement for consumption, in units of metric tons per year and as a fraction of total regional rice production.[*] VC requirements are a very small percentage of the overall crop, and the VC either control or have access to the total rural economy.

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[*]These numbers are conservative in that they are probably high; a factor of 750 grams per VC per day was used which is an "ideal" figure that they rarely achieve.
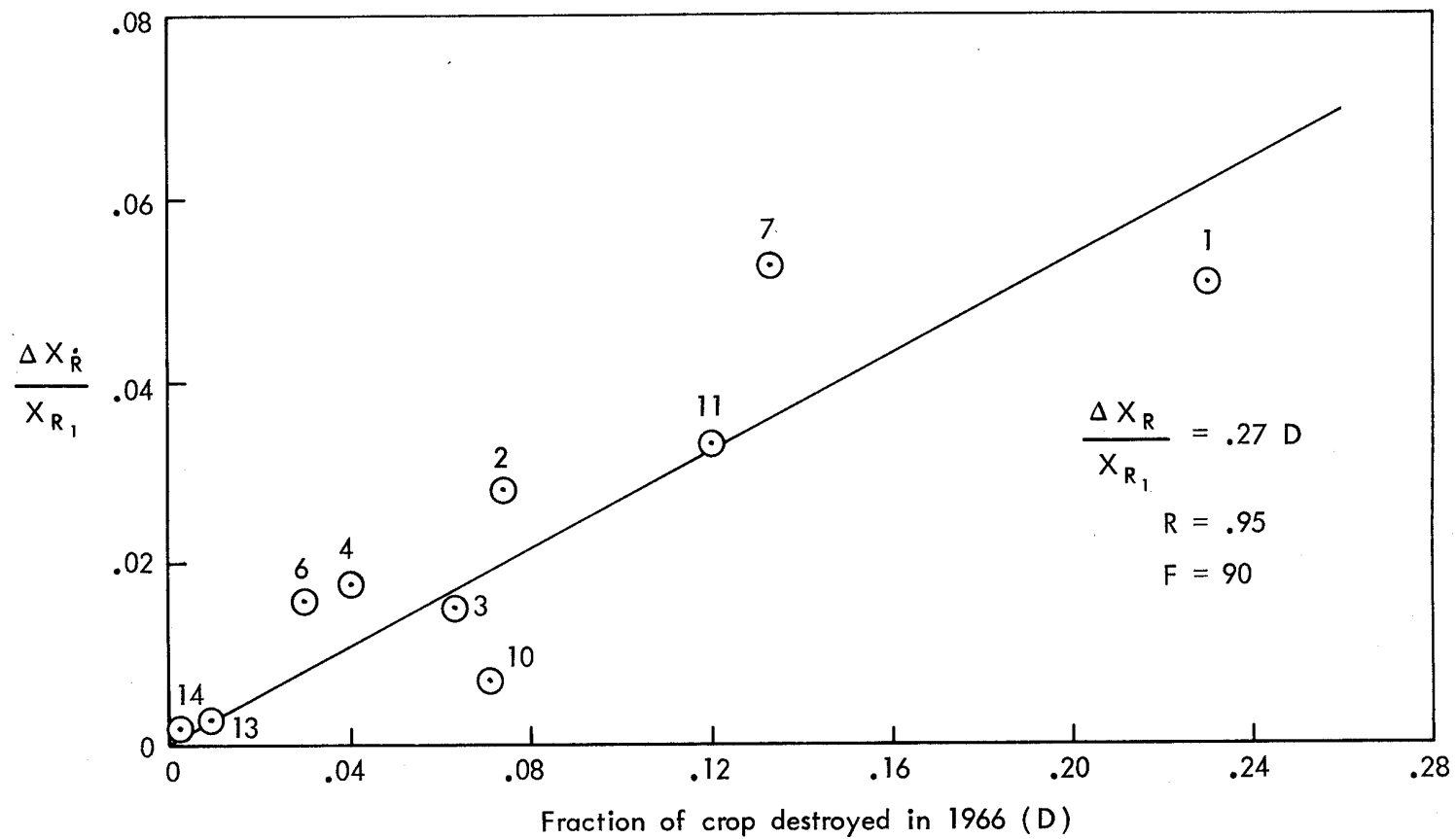
Fig. 4—Fractional loss to VC $\left(\dfrac{\Delta X_R}{X_{R_1}}\right)$ versus fraction of crop destroyed in 1966

Table 6

BASIC STATISTICS AND CALCULATIONS

Region (1)	Estimated Number of VC[a] (2)	Annual VC Consumption Requirements, Metric Tons/ Year (3)	Annual VC Consumption as Fraction of Total Production (4)	Estimated Amount of Rice Destroyed in 1966, Metric Tons (5)	Amount Destroyed divided by Amount Required (6)	Number People Affected (7)	Estimated Amount of Rice Denied VC in 1966 Metric Tons (8)	Amount Denied VC divided by Total Amount Destroyed (9)
1	6,800	1,860	.047	9,200	4.94	62,900	83	.009
2	15,000	4,110	.049	6,150	1.50	34,300	80	.013
3	27,500	7,540	.053	8,930	1.18	62,100	92	.010
4	14,900	4,080	.030	5,500	1.35	24,700	53	.010
6	17,100	4,690	.022	6,270	1.34	24,000	57	.009
7	12,600	3,450	.052	8,840	2.56	43,700	136	.015
10	19,800	5,430	.160	2,420	.45	30,600	33	.014
11	5,800	1,590	.035	5,380	3.39	29,600	49	.009
13	15,800	4,330	.019	1,970	.45	10,500	13	.007
14	22,700	6,220	.012	1,380	.22	2,300	12	.009
Total	158,000	43,300	.011	56,000	1.29	325,000	608	.011

These two facts lead inevitably to the conclusion that they should
have no serious problems in gaining rice in the amounts they require.*
They need little rice relative to the size of the total crop, yet they
control, or have access to, almost all of that crop in one way or an-
other. Their source of rice is very diffuse. If they are to be sub-
stantially hampered by the crop destruction program it will be
necessary to destroy large portions of the rural economy -- probably
50 percent or more.

The conclusions are supported by intelligence sources which
indicates that the VC have access to more food than they
need through production, purchase, taxation, confiscation, theft, and
imports. Although shortages are reported in the Central Highlands,
the problem is not the acquisition but the transportation of food
from the source to consuming units.

Columns (5) through (9) in Table 6 give added feeling for the
overall impact of the crop destruction program. These numbers are,
naturally, rough estimates, but precision is not required here.
Column (5), the estimated amount of rice destroyed in 1966, was cal-
culated by multiplying the number of crop destruction sorties flown
in each region by a factor of 125 hectares per sortie times the mean
rice production per hectare for the region. Column (6) is simply the
ratio of the amount of rice destroyed to the amount required by the VC
for one year's consumption. Seen this way, the magnitude of the crop
destruction program is indeed large; the total amount of rice destroyed
in 1966 (56,000 metric tons) was enough to feed the estimated number
of VC in these ten regions (about two-thirds of the estimated country-
wide total number of VC) for a period of about 16 months. In the most

*See Appendix A for statistics on control patterns.

extreme case (region 1, Quang Tri province) about five times as much rice as the VC need for one year's consumption was destroyed. Column (6) is compared with $\Delta X_R / X_{R_1}$ in the scatter diagram in Fig. 5.

Column (7) gives a rough idea of how many civilians had their crops destroyed in 1966. These are estimates derived by multiplying the number of hectares of land destroyed by the average regional population density in terms of population per hectare. An estimated total of 325,000 people had their crops sprayed in 1966.

Estimates of the amount of rice actually denied the VC are shown in column (8). These estimates are derived from the model and estimates of the number of Viet Cong (column 2):

$$\text{rice denied VC} = \frac{\Delta X_R \times \text{number of VC}}{2740}$$

2740 is simply a factor to change the units from grams per day to metric tons per year. For all ten regions it is estimated that 608 metric tons of rice were denied the VC in 1966 -- out of a total of 56,000 metric tons destroyed.
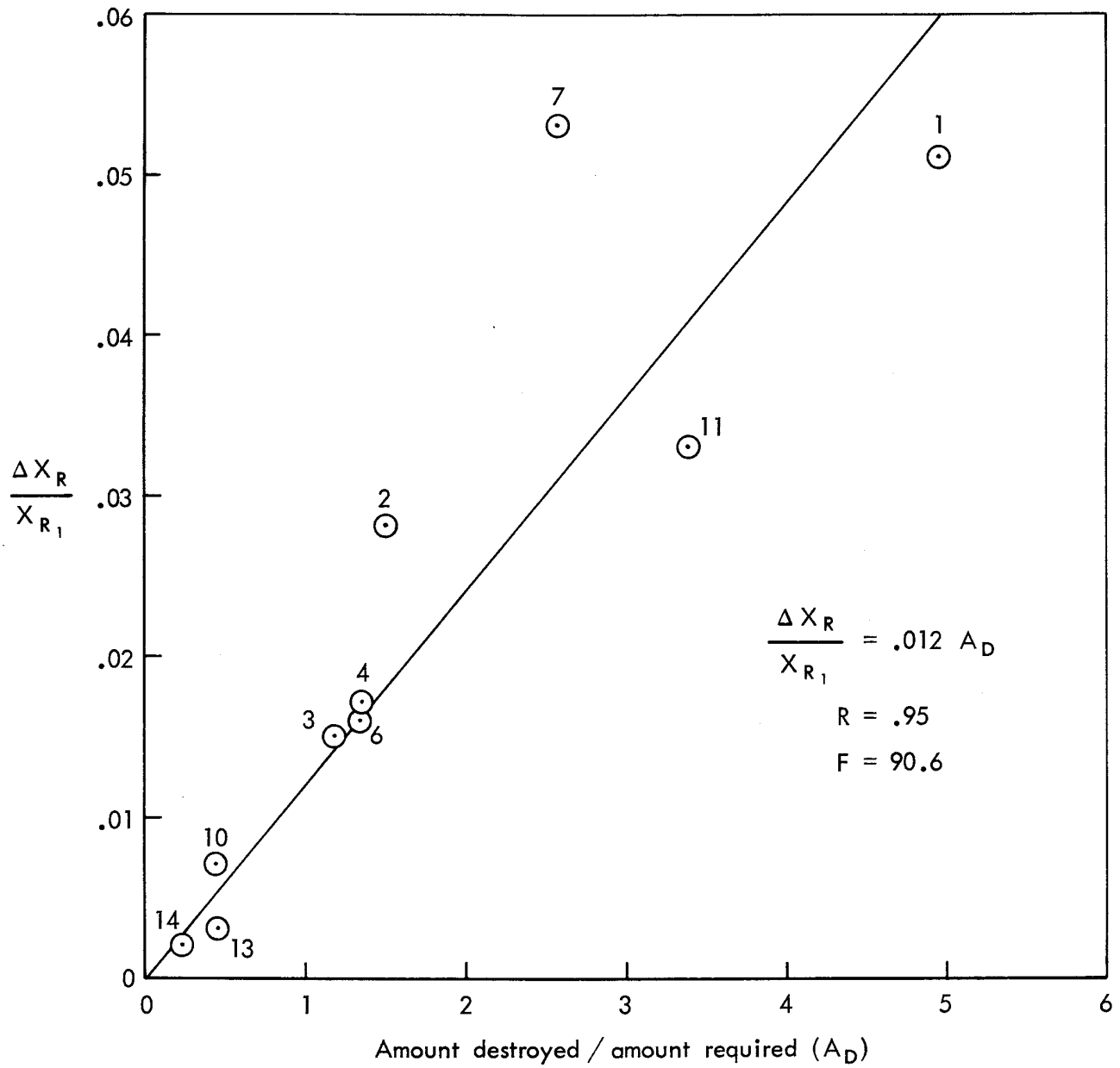
Fig. 5—$\frac{\Delta X_R}{X_{R_1}}$ versus A_D

IV. COSTS TO THE PEASANTS

A comparison of the number of people who lose their crops to the amount of rice denied the VC permits an estimate of what the crop destruction program costs the villager. Columns (7) and (8) are compared in Fig. 6. Roughly 535 people are affected for each metric ton of rice denied the Viet Cong. One ton of rice provides an adequate yearly ration for about four Viet Cong. Therefore, about 134 people experience crop loss for each yearly individual Viet Cong ration denied. The per capita loss is estimated at .172 metric tons per person or an average of about 470 grams per person per day for those people affected by spray:

estimated per capita loss (1966) = total amount of rice destroyed in 1966 divided by total number of people affected by crop spray

= 56,000 metric tons of rice divided by 325,000 people affected

= .172 metric tons/person-year

= 470 grams/person-day.

It is necessary to emphasize that this is only an estimate and is accurate only in its order of magnitude; the number of hectares destroyed in each region have been multiplied by the regional average population per hectare and, of course, within each region population per hectare is expected to vary; therefore, the estimated 325,000 people affected by crop spray in 1966 must be considered to be an "educated guess." There are grounds, however, for feeling that 325,000 is a low estimate:

(1) Crop spray operations tend to be directed toward areas of more strict VC control.

(2) There is a distinct population pattern associated with control status (see Table A-1). Stronger VC control is associated with hamlets with smaller-than-average populations.

(3) South Vietnamese provinces with small average hamlet populations tend to have high populations per hectare
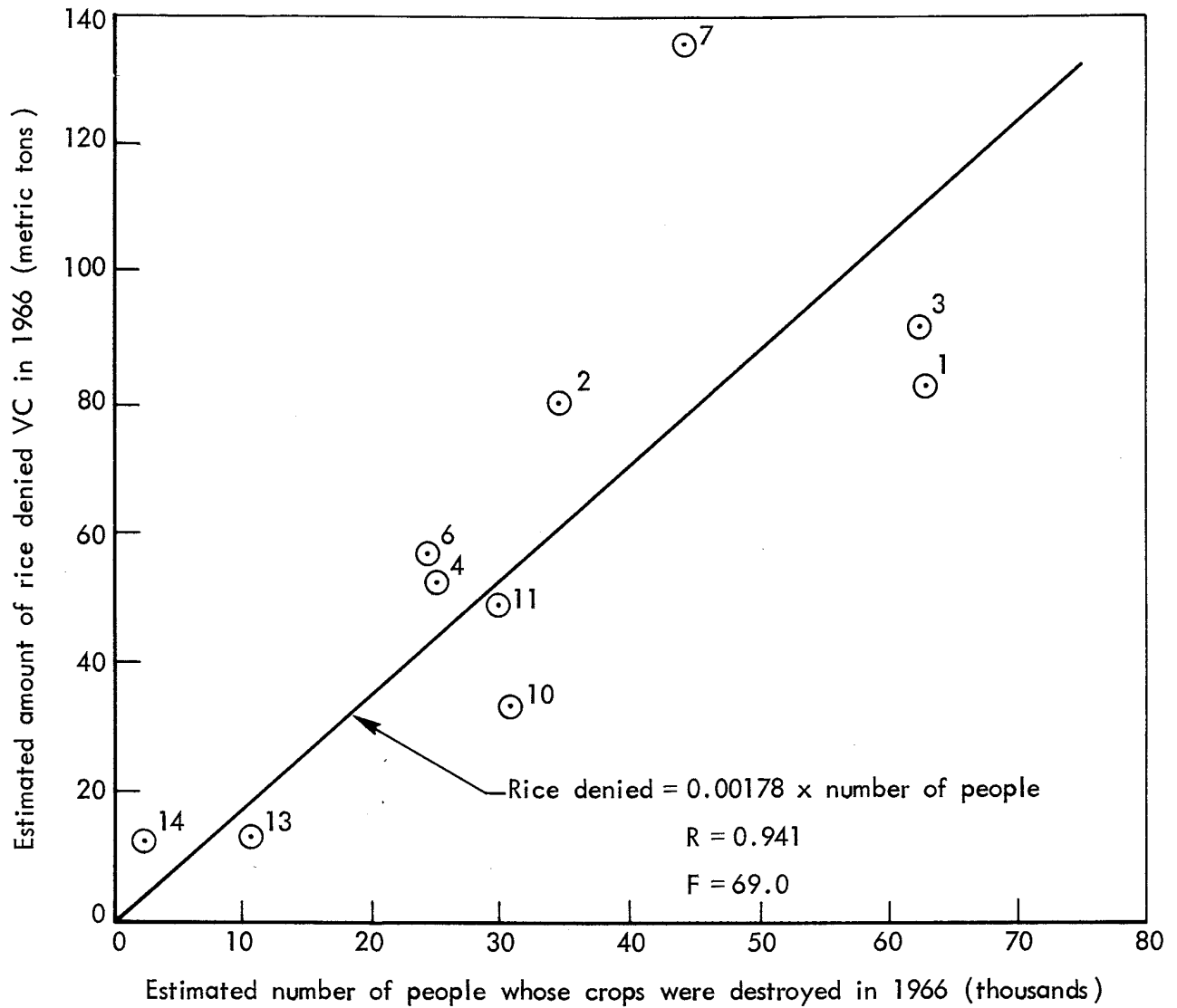
Fig. 6—Costs to civilian population

of rice land. Average population per hectare and aver-
age population per hamlet for all provinces are related
with a correlation coefficient of -.414 and a t-value
of -2.84 which is highly significant (it is unlikely
that the association exists by chance).

To summarize, since small hamlets tend to be VC-controlled (where the
spraying occurs) and have higher populations per hectare, then the areas
that were sprayed may have higher populations per hectare than the
regional averages. Thus the estimate of 325,000 people affected by
spray may be low. The order of magnitude, hundreds of thousands, is
undoubtedly correct.

V. EFFECTIVENESS OF THE CROP DESTRUCTION PROGRAM

A logical way to define the effectiveness of the program might be the following:

$$\text{effectiveness} = \frac{\text{amount of rice denied VC}}{\text{total amount of rice destroyed}} \ .$$

Calculations for each region are shown in Table 6, column (9). Although the numbers vary somewhat, they are extremely low for all regions; for all ten regions taken together the rating is about .011, or 1.1 percent.

Columns (5) and (8) are plotted in Fig. 7. Effectiveness, as it is defined here, is the slope of the least-squares line fitted through the origin -- about one ton of rice is denied the VC for each 100 tons destroyed.

The estimated "amount of rice denied VC" is the amount denied at the consumption level; therefore, "effectiveness" as it is defined here has specific conceptual limits. The VC rice ration model used in this analysis is a consumption predictor and says nothing about possible strains in VC logistics pipelines that could come as a result of crop spraying. If there are any such strains they are not reflected at the consumption level.

The VC's well-developed and effective logistics system is probably one reason for the minimal effect of the crop spray program. They can use their system to average out losses incurred in any particular area. Generally, a large portion of the agricultural and other taxes collected in the villages is transferred to province echelons, centrally pooled, and then redistributed. At the village level the VC keep only about 10 percent of what is collected.* Since the VC collect resources from all parts of the rural economy and pool them at high echelons, it follows that the decrease in resource inputs should be approximately proportional to the fraction of the overall economy destroyed; that is, in fact, what the results of the regression

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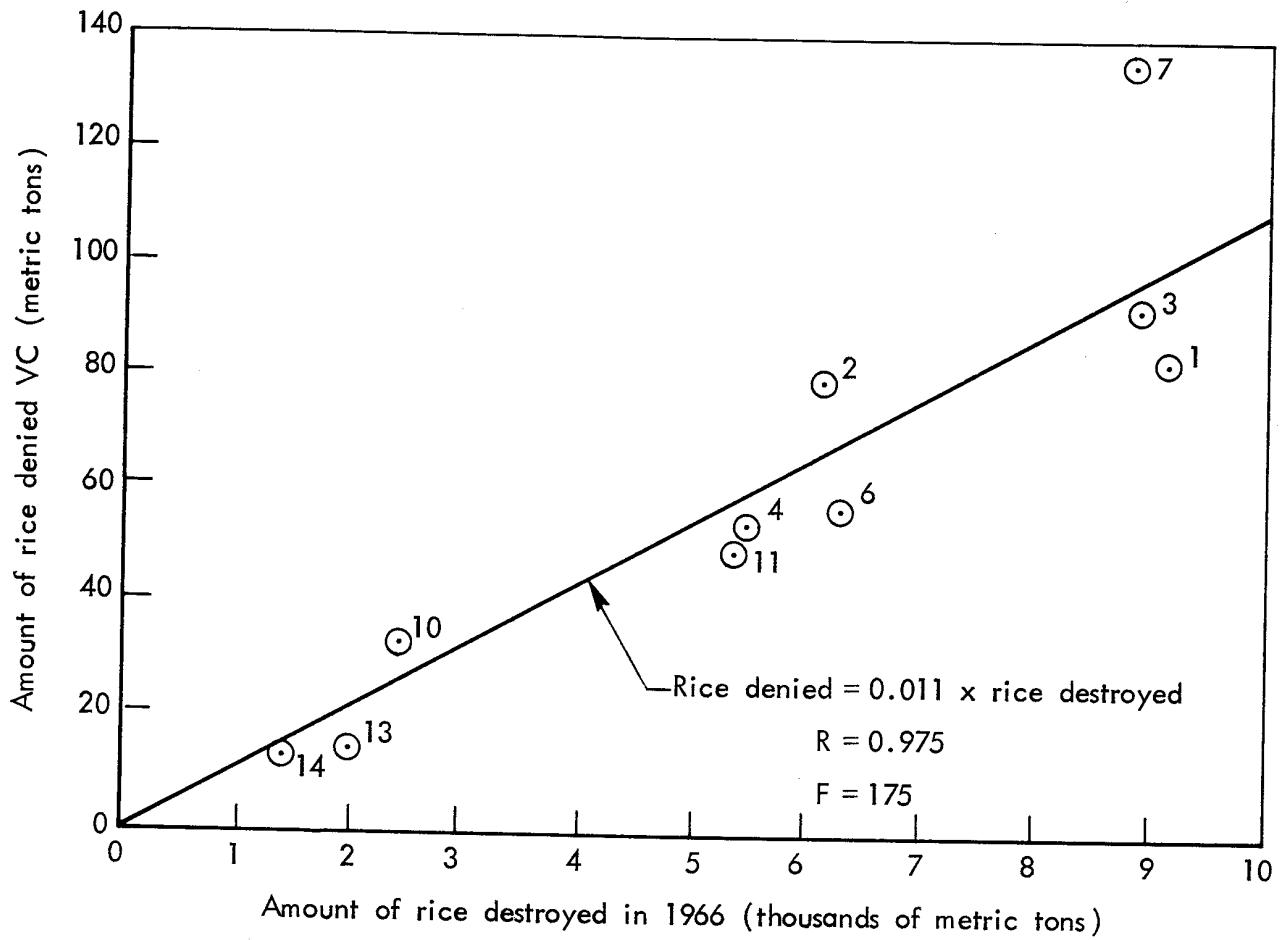*Personal communication. V. Pohle, The RAND Corporation.

Fig. 7—Effectiveness of crop-spray program

model indicate (see Fig. 4). Actually the model shows a fractional decrease in VC consumption somewhat less than the portion of the regional rice crop destroyed ($\Delta X_R / X_{R_1}$ = .27D). This result may reflect the flexibility of the system; that is, when the tax base is diminished by crop destruction the VC may divert part of their resource-gathering apparatus to purchase, confiscation, increased taxes in areas not sprayed, increased tolls at highway checkpoints, and the like.

VI. A DEDUCTIVE MODEL

Here a simple deductive model is developed to see if one can approximate the results of the multiple regression model within a reasonable set of assumptions. First, assume the total amount consumed by the Viet Cong (C_{vc}) is proportional to total rice production (P)

$$C_{vc} = kP \tag{8}$$

where k is an overall average tax rate. Next let P be altered by a fraction D of the crop. The change in consumption is

$$\Delta C_{vc} = C_{vc_1} - C_{vc_2} = k_1 P_1 - k_2 P_2 \; . \tag{9}$$

Since $P_2 \equiv P_1(1-D)$ (9) can be written as follows:

$$\Delta C_{vc} = k_1 P_1 - k_2 P_1 (1-D) \; . \tag{10}$$

Next assume that the VC raise their overall tax rate by some fraction δ. Then $k_2 = k_1(1+\delta)$ and (10) is rewritten

$$\Delta C_{vc} = k_1 P_1 - k_1 P_1 (1+\delta)(1-D) \; . \tag{11}$$

or, collecting terms,

$$\Delta C_{vc} = k_1 P_1 \left[D(1+\delta) - \delta \right] \; . \tag{12}$$

The fractional change is simply

$$\frac{\Delta C_{vc}}{C_{vc_1}} = D(1+\delta) - \delta \; . \tag{13}$$

It is interesting to study the relationship between δ and D for $\Delta C_{vc} = 0$, that is, the fractional increase in the overall average tax rate required to sustain VC consumption at its normal rate in the face

of crop destruction in the amount of D. Solution for δ at $\Delta C_{vc} = 0$ gives

$$\delta = \frac{D}{1-D} . \tag{14}$$

Hence, in terms of the deductive model, the VC would have to increase their tax rate by approximately the same fraction as D for small D; for example, for D = .100, δ = .111. It is only at high values of D that δ is significantly larger than D. The VC have demonstrated their ability to double and even increase by manifold proportions the rates at which they tax the populace.[*]

One useful criterion might be the difference between δ and D. When δ becomes substantially greater than D the VC might experience real trouble. In terms of the deductive model

$$\delta - D = \frac{D^2}{1-D} . \tag{15}$$

Equation (15) is graphed in Fig. 8. Arbitrarily we select the point at which δ - D begins to explode as D = .5. Even here the value of δ is 1.0 (which means the overall tax rate has to be doubled) and, as stated above, the VC have demonstrated their ability to increase tax rates many times over. In any case, it seems as though very high D values would be required before the VC are hurt substantially -- D values so high that major portions of the economy would be destroyed. The simple "common sense" model developed here appears to support substantially the results of the earlier regression analysis.

The results of both the regression model and the simple deductive model seem logical because of one simple point referred to above: the Viet Cong have control over, or access to, most of the rural area. They have access to a population many times greater than their total number; and their logistics system, though primitive by some standards, is well-developed and effective.

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[*] For discussions of VC tax policies, see Douglas Pike, _Viet Cong_, Massachusetts Institute of Technology Press, Cambridge, Mass., 1966, pp. 297-305; W. P. Davison, _Some Observations on Viet Cong Operation in the Villages_, The RAND Corporation, RM-5267-ISA/ARPA, July 1967, p. 85.
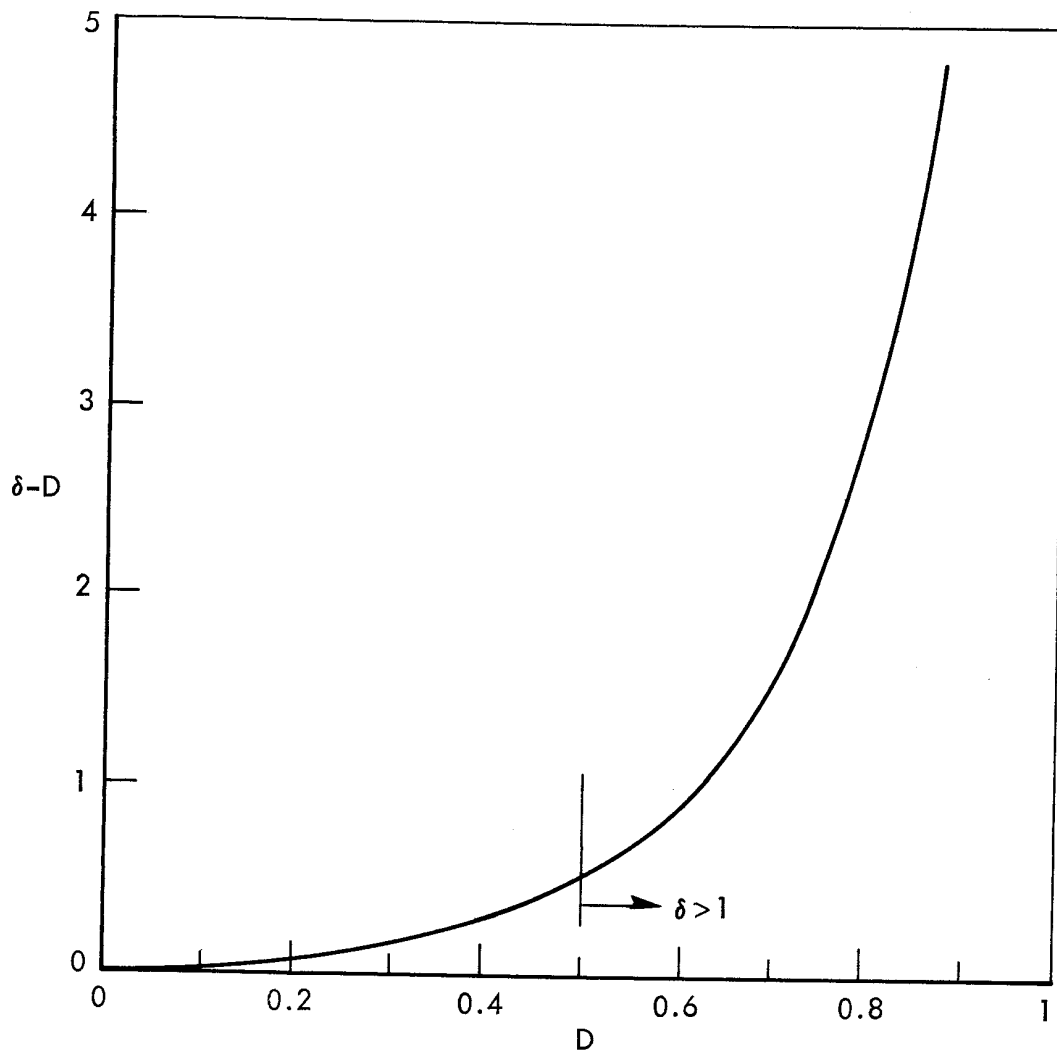
Fig. 8—Deductive model

VII. CONCLUSIONS

The empirical model that has been the primary tool in this analysis gives strong indications that VC rice consumption is closely dependent on regional economic variables and is only minimally, if at all, influenced by crop spraying.

The model lends weight to the contention that there is a high degree of intimacy between the Viet Cong and the overall rural economy of South Vietnam, because VC rice rations are a function of <u>overall</u> regional economic and population variables. No variables were used that were measures of production and population in "VC-controlled" areas alone. The VC are a small part of the population within which they move, but they are virtually woven throughout the fabric of that population; therefore, to produce any significant disruption in their rice consumption with such measures as crop spraying, it would be necessary to attack major portions of the fabric. Such measures would very likely be self-defeating.

The regression model developed here has many shortcomings -- the paucity of data, the fact that it does not take dynamic effects into account, and its inability to describe local effects (as opposed to regional averages) all mean that it is indeed very fallible. On the other hand, the results are so strong that they have to be taken quite seriously regardless of the shortcomings of the data and the methodology used in the analysis.

In terms of denying food to the VC, the returns from the crop destruction program seem insignificant at best, and the costs to the villager seem disproportionately high.

The program should be taken under serious review; based on the analysis presented here and on opinions shaped by field experience in South Vietnam, the author's feeling is that the program should be discontinued.

APPENDIX

Some recently published statistics (see Table A-1) on control patterns also support the contention that the VC have control over or access to virtually the entire rural economy. These statistics are based on the new hamlet evaluation system.[*] Note that only 168 hamlets are classed as being under "total" GVN control. Even in areas where GVN control predominates the VC can gain resources by means of covert purchase or hit-and-run raids if not by direct taxation. In areas falling toward the "total-VC-control" end of the spectrum, resources are extracted from the population most frequently by taxation or confiscation. By one means or another the VC have access to resources in all six areas (that is, the six control categories given in Table A-1).

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[*] As an interesting aside, note the average hamlet population (column 3 in Table A-1) calculated by dividing column 1 into column 2; there is a perfect rank correlation between average hamlet population and degree of GVN control. This pattern most likely reflects the tendency of smaller hamlets to be the more remote ones where, naturally, the VC tend to be stronger.

Table A-1

RURAL POPULATION AND CONTROL PATTERNS[a]

Control Status	Number of Hamlets	Rural Population[b]	Mean Hamlet Population
	(1)	(2)	(3)
Total GVN	168	489,300	2,950
Partial GVN	1,776	3,129,100	1,750
Contested (GVN leaning)	3,245	4,360,600	1,342
Contested (VC leaning)	2,156	1,976,100	918
Partial VC	528	402,200	760
Total VC	3,978	2,923,200	738
Unclassified	686	152,300	222
Total	12,537	13,432,800	1,071

Notes:

[a]These are official data compiled under the new hamlet evaluation system (a reporting program instituted in January 1967). Columns (1) and (2) were reported in The New York Times, August 7, 1967, p. 14.

[b]The urban population, all under GVN control, is estimated at 3,732,000.